

GBA Brewing Water Chemistry Primer – October 2009

Goal:

The goal of this primer is to teach home brewers how to take distilled water and turn it into top quality brewing water specific to each style of beer. In general, the water chemistry contributes to both the efficiency of your mash and the flavor of the finished beer. In the mash, the chemistry of the water helps maintain the proper pH of 5.2-5.5 so that you can have optimal starch conversion to fermentable sugars. In the finished beer, the water chemistry helps accentuate malt and or hoppy flavors. The goal is to teach you practical skills to brew better beer without necessarily understanding all the details of brewing water chemistry.

Items you will need:

1. Scale that will measure in 0.1 gram resolution.
2. Selection of brewing salts: gypsum (calcium sulfate or CaSO_4), epsom salts (magnesium sulfate or MgSO_4), calcium chloride (CaCl_2), baking soda (sodium bicarbonate or NaHCO_3), Chalk (Calcium Carbonate or CaCO_3) and table salt (sodium chloride or NaCl).
3. A reliable source of distilled water or reverse osmosis (RO) treated water. Both are effectively pure water for brewing purposes. Many health food stores sell this by the gallon.
4. Brewing software such as Promash, Beersmith or Beer Tools. Not essential but highly recommended.

pH/hardness/alkalinity: pH is a measure of how acid or alkaline a solution is. It is important in brewing since the enzymes that are active in the mash are most effective at a pH of approximately 5.2. Hard water, rich in calcium, drives the pH down in the mash. Water hardness is a measure of how much calcium and or magnesium are in solution. Alkaline water is high in carbonates and acts to drive the pH up in the mash. Carbonates also act to provide a richer more complex malt flavor in dark beers. A grain bill composed of very pale malts will have a higher pH in distilled water than a grain bill with lots of dark specialty malts. Therefore the first goal in designing your water for a style of beer is to get an estimate of the color of the finished beer in SRM. The brewing software mentioned above will estimate color after you have entered in the grain bill. The SRM value will be used below to modify the alkalinity and hardness of your brewing water for optimal conversion in the mash and flavor in the glass!

Residual alkalinity (RA): RA is the measure of how much alkalinity is not neutralized in the mash by calcium and magnesium. In order to achieve a mash pH of 5.2, we need to balance the RA with not only the calcium and magnesium added, but most importantly with the amount of dark specialty malts. The darker the beer, the more RA you will need. If you are using mostly kilned malts use the lower estimated (see below) RA but if you are using mostly roasted malts then use the higher RA. Examples:

RA of -60 to 0 ppm for pale beers

RA 0 to 120 ppm pale amber to dark amber/copper

RA 120 to 250 ppm brown ales, porters and stouts

Malt and Hops flavor profiles: The most effective way to impact the flavor of your beer through your water chemistry is to modify the chloride to sulfate ratio (Cl:SO₄). A malty beer benefits from a higher Cl:SO₄ ratio whereas a hoppy beer is accentuated with a lower Cl:SO₄ ratio.

Cl:SO₄ Ratio examples:

- 0.0-0.5 for a hoppy beer (DIPA, IPA, etc)
- 0.5-0.75 for moderately bitter (Pale Ale)
- 0.75-1.25 balanced beer (Belgian styles, Wheat beers)
- 1.25 – 1.5 malty (Brown ale, Porter)
- 1.5-2.0 for a very malty beer (Stout)

Individual Ions: You are almost ready to design your own water profile but first lets go over the individual ions and their acceptable concentration ranges.

Calcium (Ca²⁺): minimum 50-100 ppm, over 150 probably too much. Ca is important for hardness, mash pH, and yeast flocculation (beer clarity).

Magnesium (Mg²⁺): 10-20 ppm. It is important for yeast health but some argue enough comes from the malt. Too much leads to harsh bitterness (>50ppm).

Bicarbonate (HCO₃⁻): 0-50ppm for light colored beers, 50-150 for pale ales, amber, browns; 250-300 is for dark browns and stouts, never go above 300 ppm.

Sulfate (SO₄²⁻): 50-150 ppm in normal bitter beers, 150-300 for IPAs and other highly bitter beers

Sodium (Na): 0-150 ppm, sodium is not that important in its own right

Chloride (Cl): 0-250 ppm, useful to round out the malt character.

How to design your water profile:

1. With the predicted color of your beer, in SRM, go to the following online water chemistry calculator: <http://www.franklinbrew.org/tools/rac.html> and enter in the SRM into the “target color box”. This will predict the RA for you. You can also use John Palmers water chemistry spreadsheet which can be downloaded here; <http://www.howtobrew.com/section3/chapter15-3.html>.
2. Now you can skip lines 2 and 3 in the calculator, I find them to be a waste of time. In line 4 begin by entering in grams of salts (grams per gallon), usually in the .1-1 g range, taking in mind the recommendations from above. Start with 0.25 g of epsom salts for good measure and then add calcium into a reasonable range (>50 ppm) since it is important for all beers. If it is a hoppy beer, use gypsum or for a malty beer use calcium chloride. Next, dial in the residual alkalinity (RA) of the water, which you will notice is increased with ions containing carbonates and decreased by calcium (hardness). This takes playing around because you will notice when you are trying to dial in your RA, you might be changing your Cl:SO₄ ratio and vice versa. Baking soda is more effective at raising the RA than chalk since the hardness of the calcium in chalk combats the alkalinity of the carbonate.
3. Once you have created your water, transfer the information manually into promash and save the water style. Promash will also allow you to check the bicarbonate ion concentration, since that information is not available on the online spreadsheet.
4. On brew day, first make up the appropriate amount of brewing water for your mash, and add the salts directly to the mash because chalk will not dissolve into distilled

water. After mashing, sparge using distilled water. Finally add more salts to the start of the boil to make up for the difference between salts added in the mash and the final volume of the beer (after evaporation in the kettle). So if you mashed with 4 gallons of water (with salts) and you are making a 6 gallon batch, you will need to add 2 more “gallons” worth of salts.

Other points of clarification:

pH of the brewing water does not really matter because you do not really know how buffered the pH is. What actually matters is the pH of the mash and this is determined by the RA of the water coupled with the grain bill.

Acids: Lactic has a flavor, phosphoric acid can ppt Ca in a mash. 1-2 mls per gallon will work and not make beer too sour. But if you follow the guidelines above you will not need to add acids to your mash.

Further Reading: Check out the book – John Palmer “How To Brew”, the first edition is available free online here: <http://www.howtobrew.com/>

Example water chemistry:

1. Czech pilsner: balanced beer with respect to Cl:SO₄ and maltiness:bitterness but brewed with a light mineral profile. Start with distilled, add Ca to at least 50... and keep Cl:SO₄ ratio balanced. Do not accentuate the bitterness as much as a german pils. Use a combination from gypsum and CaCl₂, so that the Cl:SO₄ ratio balanced.

2. German Pilsner: biting dry and accentuated bitterness. Majority of Ca comes from gypsum so that the CL:SO₄ ratio is lower. 65-75 ppm Ca.

3. Munich Helles: medium mineral content water. Ca 50-70 ppm range, but you do not want SO₄ to dominate, you want the Cl to dominate... use more CaCl than gypsum.

4. Dortmunder: Balanced beer, with overall more minerals. Want a RA that supports the color at 4-6 SRM... little darker than german pils or helles, want a balanced Cl:SO₄. 200 ppm Ca, 10-20 ppm Mg, 150ppm TA, Cl: 100pm and 100pm SO₄.

5. IPA: Low Cl:SO₄ ratio with most of the calcium coming from gypsum.

7. ESB: A copper colored beer, add equal amounts gypsum:chalk. This gives a good RA for the color of the beer. It is known for a round malt character, to accentuate that you can back off gypsum and add some CaCl₂ to increase Cl and ultimately increase the Cl:SO₄ ratio. Cl can be as high as 150 or 200 ppM.

8. Dry stout: Do no need much sulfate... more balanced Cl:SO₄ or more to the Cl side of the ratio. Easy to let this get too acidic, without enough carbonate. RA 200ppm. With ahigh RA water you can taste all the specialty malts, but without you get a one dimensional roast character.

9. McDoles Pale water:

Ca – 105.6, **Mg** – 18.3, **Na** – 20.8, **SO4** – 307.9, **Cl** – 44.8, **HCO3** – 0

Gypsum – 1.6 g, **Epsom Salt** - 0.7 g, **NaCl** – 0.2 g, **CaCl2** - 0.1 g (grams per gallon)

A discussion on Sac water from Dave Bosworth:

“Sac water is rated as one of the highest in water quality in the country for major metropolitan areas. You can definitely use it for brewing. I think that they use chlorine for disinfecting. Both chlorine and chloramine can be removed by carbon filtration or a half of a campden tablet. Here are the typical values of ions found in Sac drinking water based on the 2008 water quality report and discussions with scientists at the water quality lab.....

Ca: 22 ppm

Mg: 5.6 ppm

Na: 8.0 ppm

Cl: 12.2 ppm

SO₄: 13 ppm

HCO₃: 55 ppm

For all grain brewing, I normally cut my tap water in half with RO water to bring down the bicarbonate for lighter styles. Otherwise, the water is fine for darker styles. Hope this helps.”